

Life support in hemodialysis emergencies—treatment standard

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ABSTRACT

Hemodialysis removes uremic toxins and excess water and sodium from the blood of patients with kidney failure. For the last 60 years, this technique has been extensively improved in order to optimize patient survival and minimize adverse events. Indeed, life-threatening complications related to hemodialysis have become very rare with the use of modern machines and equipment. These hemodialysis-related serious events that became less frequent include hemolysis, air embolism, dialyzer reactions and dialysis disequilibrium syndrome. On the other hand, other medical emergencies are regularly encountered in hemodialysis units such as arrhythmia, acute coronary syndrome, stroke, epilepsy, trauma, sepsis, allergic reactions, or bleeding related or not to vascular access. Cardiac arrest can also occur suddenly or as a result of the severity of medical events or delay in their management. In fact, patients on hemodialysis have multiple comorbidities and are subject to common complications that need to be promptly recognized and timely managed by the dialysis staff. Nephrologists taking care of these high-risk patients need a practical, efficient approach to provide care and save lives. Based on the European Resuscitation Council Guidelines, the Resuscitation Council UK, the American Heart Association, and the Advanced Trauma Life Support, we review here the current standards of life support and propose a systematic approach to be used in the hemodialysis setting, that helps healthcare providers in their assessment and management of vital emergencies.

Keywords: cardiopulmonary resuscitation, emergencies, hemodialysis, life support, life-threatening

IN A NUTSHELL

1. Patients on hemodialysis have multiple comorbidities and are at high risk to develop medical emergencies requiring a prompt and systematic management.
2. Medical emergencies without cardiac arrest need to be assessed and managed following the ABCDE (Airway, Breathing, Circulation, Disability and Exposure) approach. Given that hemodialysis puts patients at high risk of bleeding and technique-related adverse events, we propose to follow the XT-ABCDE approach in hemodialysis where X stands for exsanguination/bleeding and T stands for technique-related events.
3. Cardiac arrest is defined as unconsciousness, with no breathing or only gasping. Very early recognition of cardiac arrest improves patient resuscitation and outcome. Management of cardiac arrest in hemodialysis requires following the universal CAB (Circulation, Airway, Breathing) approach that prioritizes circulation and includes applying uninterrupted chest compressions and early defibrillation.
4. Patients on hemodialysis are at high risk of reversible causes of cardiac arrest such as hyperkalemia, hypokalemia or hypomagnesemia. Resuscitation should be continued until a reversible cause is treated.
5. Ethical considerations including respecting the patient's wishes are mandatory while managing medical emergencies in patients on hemodialysis.

INTRODUCTION

Hemodialysis removes toxins, excess water and sodium from the blood of kidney failure patients. The bloodstream is regularly connected to an extracorporeal circuit, via the vascular access (VA). Over the past six decades, this technique has improved, making complications such as hemolysis, air embolism, dialyzer reactions

and dialysis disequilibrium syndrome much rarer [1, 2]. However, many other medical emergencies are faced in hemodialysis due to associated comorbidities.

A medical emergency is an acute condition threatening a person's life or long-term health. Patients on hemodialysis are at risk for various emergencies [1–4], including severe bleeding,

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cardiovascular events, septic, pulmonary or neurological emergencies [1, 4]. Additionally, sudden cardiac arrest is relatively common in patients on hemodialysis [5–13]. A nephrologist should be trained to promptly assess and manage medical emergencies. This basic life support is critical before transferring the patient to the intensive care unit (ICU). So far, there are no published resuscitation guidelines focusing on hemodialysis. Within the section on special settings, the European Resuscitation Council Guidelines only described very briefly the management of cardiac arrest in dialysis including potentially reversible causes and nurse-led defibrillation [14, 15]. Therefore, we here review the current standards of the 2021 European Resuscitation Council Guidelines, the Resuscitation Council UK, the 2020 American Heart Association Guideline, the 2024 International Consensus on Cardiopulmonary Resuscitation and the Advanced Trauma Life Support [14–20]. We propose an effective and systematic approach to deal with most medical emergencies, incorporating a universal resuscitation algorithm tailored to the hemodialysis population.

AT FIRST GLANCE

In a hemodialysis unit, the nephrologist—called to address one of three urgent symptoms: acute pain, unresponsiveness or abnormal breathing—should first assess whether the patient is experiencing cardiac arrest (Fig. 1). Based on the European Resuscitation Council Guidelines and the American Heart Association Guideline, a cardiac arrest is suspected when a patient is unresponsive with no breathing or only gasping [14, 17, 19]. Cardiac arrest requires calling the medical emergency team and applying the CAB (Circulation, Airway, Breathing) approach, prioritizing circulation by promptly applying continuous chest compressions [14, 19]. In case of no cardiac arrest, we propose the XT-ABCDE method. ABCDE is a popular strategy used to prevent cardiac arrest in acute critical illnesses, it is followed by first aid rescuers and evaluates consecutively Airway, Breathing, Circulation, Disability and Exposure [14, 15, 18]. Adding X at the beginning, by trauma life support experts, underscores the importance of ruling out, first, catastrophic hemorrhage or exsanguination [20]. In the setting of hemodialysis, we propose to add T next to X, where T stands for Technique-related life-threatening events such as hemolysis, air embolism and anaphylaxis that require disposing of the extracorporeal blood as a first step.

EMERGENCIES WITHOUT CARDIAC ARREST

How they present

Excluding cardiac arrest, medical emergencies in hemodialysis typically present in four ways: unresponsiveness from a neurological event or shock (hypovolemic, anaphylactic, septic or cardiogenic), abnormal breathing from airway obstruction/respiratory distress, acute pain/discomfort or active bleeding. In 2012, Galhotra *et al.* analyzed medical emergencies, in 8928 hemodialysis inpatients, over a 64-month period [3]. They reported 118 events requiring rapid response system activation (12 events per 1000 patients). The most common emergency was neurological, occurring in 29% of cases (24% for mental status change, 5% for seizure) followed by respiratory distress/hypoxemia in 27% of them. Severe hypotension occurred in 11%, arrhythmia in 9%, chest pain in 7%, uncontrolled bleeding in 3% and cardiac arrest in 4% of cases. Notably, 12 events occurred before starting dialysis and 19 events after the session had ended while awaiting transportation [3].

Prognosis of medical emergencies in patients on hemodialysis

Medical emergencies in patients on hemodialysis have a mortality rate approximately six times higher than in the general in-hospital population [3]. Galhotra *et al.* showed that patients admitted following neurological or cardiovascular emergencies have better survival than those admitted for respiratory distress [3]. These data emphasize the importance of a prompt management of these high-risk patients.

CARDIAC ARREST

Definition of cardiac arrest

Based on the American Heart Association and European Resuscitation Council guidelines, cardiac arrest is defined as unresponsiveness, with no breathing or only gasping [14, 17, 19].

Epidemiology of cardiac arrest in hemodialysis

Starks *et al.* found that 7 in 100 000 hemodialysis patients experienced in-hospital cardiac arrest and 60% of them died within 48 h [6]. Pun *et al.* found that early cardio-pulmonary resuscitation (CPR) and early defibrillator use improved survival [7]. A recent survey of 100 US dialysis technicians showed that 80% witnessed a cardiac arrest in hemodialysis, 65% had a high confidence for performing basic life support especially if they worked in large dialysis units but they had low confidence (33%) in their team's ability to provide resuscitation [21]. Among the most significant barriers perceived, delays in recognizing cardiac arrest and fear of harming the patient were the most cited [21].

TREATMENT STANDARDS

First actions

First actions generally based on the Resuscitation Council Guidelines

Within 30 seconds, the physician, attending a medical emergency, should apply the 'Look, Listen, Feel' approach [18]: if the patient is awake, ask 'How are you?', if he/she responds with short sentences or weird sounds, this may suggest breathing problems; if unconscious, shake him/her and ask 'Are you alright?'. Unresponsiveness is a critical sign and requires calling colleagues and the emergency team for help. In case of unresponsiveness, unconsciousness and no breathing, or uncertainty in pulse detection, CPR should be started as detailed below [18]. Vital signs should be monitored as soon as possible by attaching a pulse oximeter, electrocardiogram (ECG) monitor and a non-invasive blood pressure (BP) monitor. Blood testing is usually possible through the VA, otherwise an intravenous (IV) cannula should be inserted. Patient positioning depends on the suspected diagnosis (Box 1).

Additional first actions, specific to the hemodialysis population

If the patient is connected to the dialysis circuit, three swift decisions are crucial: determining whether the emergency is a reversible hypotension requiring only saline, whether dialysis should be stopped, and whether extracorporeal blood should be returned (Box 1).

Intradialytic hypotension (IDH) occurs in 11% of hemodialysis sessions, mainly from volume depletion [22, 23]. IDH is defined by KDOQI and European Best Practice guidelines as a symptomatic decrease in systolic BP ≥ 20 mmHg [24, 25], though some studies use a threshold below 90 mmHg [23]. IDH can lead to

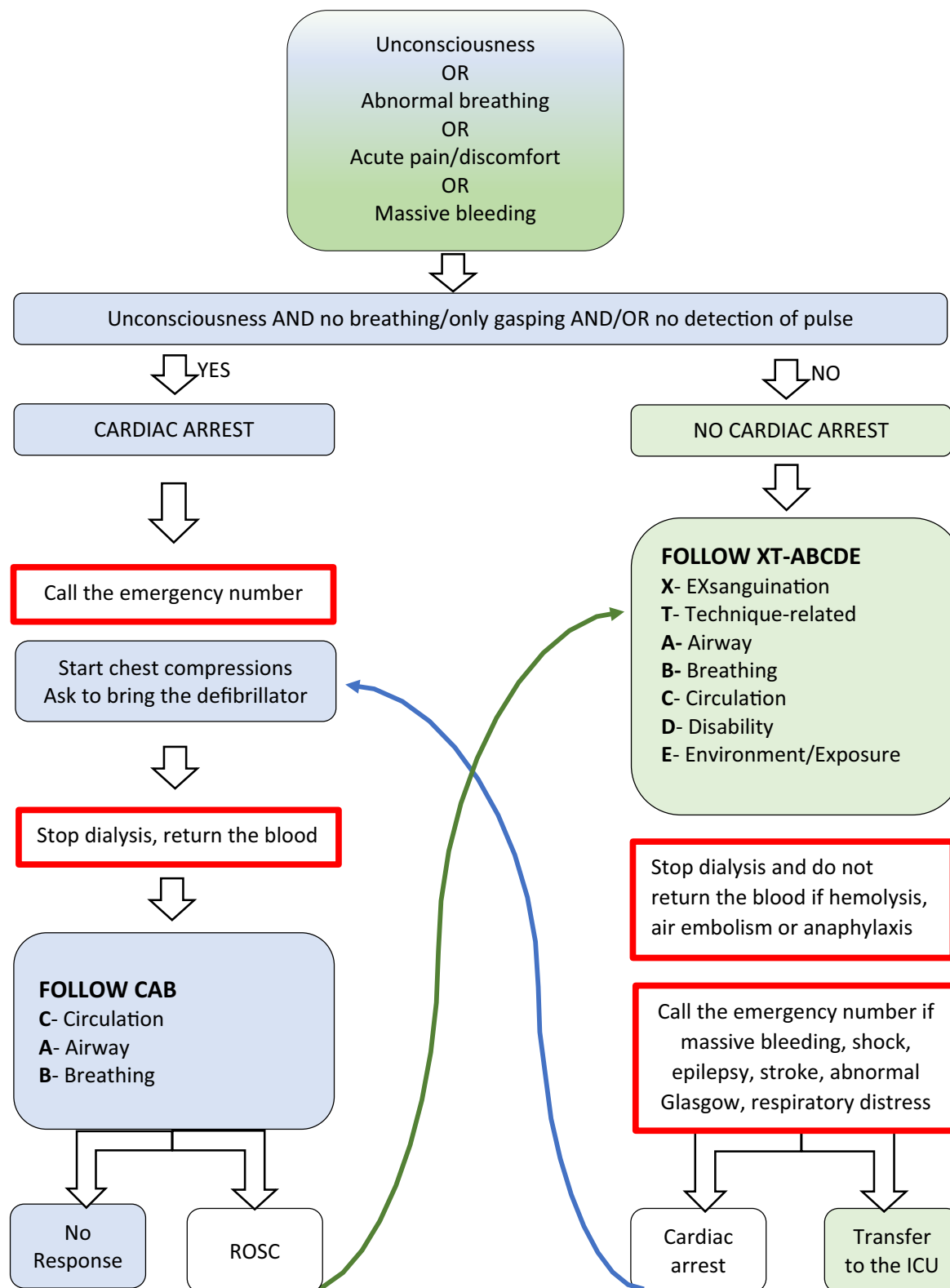


Figure 1: Flow chart of management of medical emergencies in hemodialysis.

unconsciousness and is more common in the second half of the hemodialysis session or with high ultrafiltration rates. It is typically reversed by stopping ultrafiltration, placing the patient in Trendelenburg position and giving 150–400 mL of IV isotonic saline. Persistent IDH despite saline requires further investigation.

In case of IDH with signs of anaphylaxis, hemolysis or air embolism, dialysis should be stopped and extracorporeal blood should not be returned to the patient [1, 2]. If the patient is suffering from bleeding, shock (hypovolemic, septic, cardiogenic), symptomatic arrhythmia, stroke, seizure or cardiac arrest, dialysis

Box 1. Strategies how to personalize treatments.**Patient positioning**

Trendelenburg position

- Shock
- Bleeding

When to stop dialysis

Without returning extracorporeal blood

- Suspicion of air embolism
- Suspicion of hemolysis
- Anaphylaxis

BP management in case of stroke

- The American Stroke Association and the European Stroke Organization recommend that BP be not treated if <220/110 mmHg in case of ischemic stroke not eligible for thrombolysis but they suggest that careful reduction of 15% would be reasonable if BP >220/120 mmHg [42]

Reversible causes of cardiac arrest during dialysis (the 5 Hs and the 5 Ts)

1. Hypovolemia
2. Hyperkalemia
3. Hypokalemia or Hypomagnesemia
4. Hypoxia
5. Hydrogen ion (acidosis)

Left lateral recumbent position

- Pulmonary air embolism

With safely returning extracorporeal blood

- Cardiac arrest and symptomatic arrhythmia
- Bleeding
- Shock
- Epilepsy

- For patients undergoing thrombolysis, BP should be kept below 185/100 mmHg using IV antihypertensive therapy such as nicardipine or labetalol [42, 43]

Supine position

- Cardiac arrest
- Stroke

- In patients with hyperacute cerebral hemorrhage (<6 h), they recommend lowering BP to a range between 110 and 140 mmHg [43]

should be stopped while returning extracorporeal blood. In all cases, the VA is kept open for blood testing and IV medications.

Systematic approach to medical emergencies: XT-ABCDE method

In summary

The ABCDE approach is recommended by the European Resuscitation Council Guidelines and Resuscitation Council UK for any patient with a deteriorating condition [14, 18]. This is a quick yet a complete assessment of airway, breathing, circulation, disability and exposure. In less than five minutes, a systematic assessment of all causes of vital emergencies is crucial. In a scoping review of adherence to ABCDE in emergency departments, time to completion of ABCDE varied from 2 to 6 min in simulation settings but ranged from 2 to beyond 30 min in real life [26]. Healthcare providers using a handheld checklist completed assessment faster [26].

Like trauma patients, patients on hemodialysis may benefit from adding initially X to ABCDE, because of the risk of catastrophic bleeding from the VA or circuit [20, 27]. While looking for bleeding and in case of chest pain or shortness of breath, healthcare providers should look for signs of anaphylaxis, hemolysis or air embolism. These Technique-related emergencies should be prioritized as T in the ABCDE approach: they require stopping hemodialysis without returning the extracorporeal blood.

Following the XT steps, ABCDE should be applied as in the general population (Fig. 2). Any detected life-threatening diagnosis should be treated before moving to the next part of ABCDE [18]. It is further recommended to wait some minutes to assess the effect of treatment. All team members should be solicited for help (ensuring IV access, attaching monitors). The nephrologist should ensure effective communication [18]. The ABCDE approach requires nephrologists to stay informed about the latest recommendations across major medical specialties, including pulmonary, neurological and cardiovascular resuscitation.

Catastrophic hemorrhage or eXsanguination

Battlefield Trauma Life Support (BTLS), which traditionally followed the Advanced Trauma Life Support ABCDE principles, shifted to C-ABCDE prioritizing catastrophic hemorrhage [20]. Trauma Life Support teams incorporated X-ABCDE in their training programs with X/C used interchangeably. Exsanguination—though rare—can be rapidly fatal in hemodialysis. VA bleeding must thus be ruled out first. Fatal VA hemorrhage results from (pseudo)aneurysm rupture of the arteriovenous fistula, catheter disconnection or needle dislodgment and accounts for 0.4%–0.6% of hemodialysis deaths [27, 28]. A 2007 US report found 21% of fatal bleeds from catheters, 24% from fistulas and 55% from grafts [28]. A Belgian study (2005–12) reported seven severe VA bleeds (two fatal), mainly infection-related, with an incidence of 0.045 hemorrhage/1000 patient-days [29]. Other bleeding risks include trauma occurring before reaching the unit, recent surgery, spontaneous organ bleeding and anticoagulant/antiplatelet therapy—common in patients on hemodialysis [30].

Bleeding is assessed by visually inspecting the patient, exposing the VA site and checking for environmental blood spread. Catastrophic bleeding from a ruptured fistula or graft is managed by applying direct, uninterrupted manual pressure until help arrives, keeping the patient warm, administering 500 mL boluses of isotonic saline to maintain mean arterial pressure ≥ 65 mmHg [14, 15], and calling the medical emergency team and vascular surgeon. The 2021 European Resuscitation Council guidelines recommend using a hemostatic dressing and tourniquets for limb wounds in life-threatening bleeding [31]. While some advise against tourniquets in hemodialysis patients [1, 2], recent studies suggest they may be life-saving in severe cases [32]. A tourniquet should be placed 5–7 cm above the wound, avoiding joints, and tightened until bleeding slows or stops [31]. A recent case report described controlling fistula bleeding with a bottle cap [33]. Further interventions include preparing for urgent blood transfusions and reversing anticoagulation [34] (Table 1). Importantly, no

NO CARDIAC ARREST:

	CHECK	DIAGNOSE	MANAGE
X  EXSANGUINATION	- Vascular access - External bleeding - Acute pain	- Aneurysm rupture - Needle dislodgment - Catheter	- Pressure to bleeding site 500mL IV Bolus Saline x3 - Transfusion - Reversal of anticoagulation - Call early vascular surgeon
T  TECHNIQUE-RELATED	- Shortness of breath/ chest pain - Circuit color - Circuit air bubbles - Disconnected needle or catheter - Airway swelling, wheezing, skin rash	- Hemolysis - Air Embolism - Anaphylaxis	- Do not return extracorporeal blood - High-flow Oxygen 0.5mg IM Epinephrine for anaphylaxis/IV saline - Left lateral recumbent position for pulmonary air embolism - Resume dialysis if hyperkalemia
A  AIRWAY	- Difficulty to speak - Stridor - Holding throat with hands	- Foreign body airway obstruction - Anaphylaxis	5 back blows/ Heimlich Maneuver/ Magill forceps in case of foreign body - Oxygen 0.5mg IM Epinephrine for anaphylaxis/IV saline
B  BREATHING	- Respiratory rate - SpO2 - Respiratory pattern - Chest symmetry - Auscultatory sounds - Patient color/cyanosis	- Pulmonary edema - Pulmonary embolism - Asthma - Pneumothorax - Pneumonia	- High-flow Oxygen (SpO2 94-98% for asthma and SpO2 88-92% for COPD) - Bronchodilators/Hydrocortisone 100mg IV for asthma - Anticoagulation for pulmonary embolism
C  CIRCULATION	- Capillary Refill time (abnormal if >2-3 seconds) - Pulse - Hypotension - Pale skin color/ mottling skin	- Shock (septic, anaphylactic, hypovolemic, cardiogenic, tamponade) - Arrhythmia - Myocardial infarction	- Stop dialysis and supine position+passive leg raising 30-60 degree elevation - Saline infusion 500ml, in 5 to 10 mins to maintain Mean Arterial Pressure $\geq$ 65 mmHg - Calcium gluconate for hyperkalemia - Cordarone for atrial fibrillation - Aspirin for Myocardial infarction - Lactate measurements/ antibiotics for septic shock
D  DISABILITY	- Blood sugar - Pupils - FAST/AVPU - Body temperature - Glasgow score - High blood pressure	- Stroke - Seizure - Any other neurological event - Hypoglycemia - Drug toxicity	- Give glucose if hypoglycemia and continue dialysis - For other causes, stop dialysis - Brain CTScan - Oxygen if SpO2<94% - Anti-epileptic drugs for seizure
E  ENVIRONMENT/ EXPOSURE	Head to toe examination, Front and Back	- Fever - Injuries/wounds	- Case by case: - Saline infusion - Antibiotics

Figure 2: No cardiac arrest: the XT-ABCDE approach in hemodialysis.

antidote exists for low molecular weight heparin, often used in hemodialysis in Europe.

Technique (hemodialysis)-related emergencies

Severe hemolysis results from red blood cell fragmentation within the dialysis circuit [1, 2]. Severe hemolysis presents as chest, back or abdominal pain, nausea, vomiting, diarrhea, chills and/or dyspnea. The extracorporeal blood can turn to cherry red or port wine color. Causes of severe hemolysis include mechanical causes such

as a high blood flow entering an obstructed or kinked tubing, small gauge needles or excessively negative arterial pressure. Hemolysis associated with water contaminants (chloramine, formaldehyde) became very rare. The major fatal consequence of hemolysis is hyperkalemia (Table 1). Therefore, dialysis should be stopped without returning the blood. Blood should be tested for hemolysis: haptoglobin, schizocytes, lactate dehydrogenase, Coombs test. The next step is to resume hemodialysis to treat hyperkalemia. Blood transfusions may be needed as well.

Table 1: Treatment of medical emergencies in hemodialysis.

Medical emergency	Treatment	Dose	Route	Frequency	Aim
Without cardiac arrest					
X—Exsanguination					
Hypovolemia	Saline infusion	500 mL	IV	Up to 3 times	Mean arterial pressure ≥65 mmHg
Reversal of anticoagulation					
Vitamin K antagonist	Vitamin K	10 mg IV	IV (30 min)	Once	Monitor INR and bleeding
Unfractionated heparin (UFH)	Protamine sulfate	1 mg neutralizing 80–100 UI of UFH	IV over at least 10 min	Once	
DOAC or vitamin K antagonist	Four-factor prothrombin complex concentrate (4F-PCC)	25–50 units/kg over 2–5 min	IV	Once	
Dabigatran	Idarucizumab	2500 mg over 5–10 min	IV	Twice	
Apixaban or rivaroxaban	Andexanet-alfa	30 mg/min over 15–30 min	IV	4–8 mg/min over 120 min	
T—Technique related					
Hemolysis/hyperkalemia	10% Calcium gluconate	30 mL over 5 minutes	IV	Once or twice	Monitor serum potassium and ECG
	Insulin-glucose	Glucose 25 g (250 mL of 10% glucose) + 10 UI insulin over 15–30 min	IV	Once	
Pulmonary air embolism	Salbutamol	10–20 mg	Via oxygen-driven nebulizer	Once	
Anaphylaxis	Oxygen	High-flow	Nasal	Continuous	SpO2 94%–98%
	Epinephrine	0.5 mg	IM	Once or twice after 5 min	SpO2 94%–98%
	Saline infusion	500 mL	IV	Up to 3 times	
A—Airway			Same as above		
Anaphylaxis					
B—Breathing					
Bronchospasm	Hydrocortisone	100 mg	IV	Once	SpO2 94%–98% for asthma and 88%–92% for COPD
	Salbutamol	5 mg	Via oxygen-driven nebulizer	Every 15–30 min	
	Oxygen	High-flow	Nasal	Continuous	
	UFH	80 UI/Kg	IV	Continuous	SpO2 94–98%
	Oxygen	High-Flow	Nasal	Continuous	
Pulmonary embolism					
C—Circulation					
Shock	Saline infusion	500 mL	IV	Up to three times	Mean arterial pressure ≥65 mmHg
Septic shock	Saline infusion	30 mL/kg	IV	As needed	
		IV norepinephrine within the first hour if no response to saline infusion			

Table 1: Continued

Medical emergency	Treatment	Dose	Route	Frequency	Aim
Myocardial infarction	Aspirin and discuss fibrinolysis or percutaneous coronary intervention	150–300 mg	po	Once	Monitor ECG
Atrial fibrillation	Amiodarone	150 mg over 10–20 min	IV	1 mg/min over 6 h	Monitor ECG
D—Disability Severe hypoglycemia Epilepsy (status epilepticus)	Glucose 30%	3 g	IV	As needed	Glucose ≥80 mg/dL
	Clonazepam	0.015 mg/kg (max 1 mg) bolus	IV	Repeat after 5 min	– Monitor consciousness – SpO ₂ >94%
Stroke/hypertensive emergency with BP >220/120 mmHg	Diazepam	0.2–0.25 mg/kg (max 10 mg) bolus	IV	Once	
	Oxygen	As needed			
	Nicardipine	5 mg/h	nasal IV	Continuous Adjust to BP	
	Labetalol	10–20 mg over 1–2 min	IV	Adjust to BP	
E—Exposure/environment Infection	Antibiotics	Case by case	IV	Loading dose then maintenance dose	
With cardiac arrest All cases	Epinephrine	1 mg	IV (IO)	Every 3–5 min	– Mean arterial pressure ≥65 mmHg – SpO ₂ 92%–98% – Body temperature 32–37°C – End tidal CO ₂ 35–40 mmHg – Glucose 80–180 mg/dL
After 3 shocks if ventricular fibrillation	Amiodarone	300 mg 1st dose	IV	150 mg after the 5th shock	
Bradycardia	Or lidocaine	100 mg	IV	50 mg after the 5th shock	
Hyperkalemia	Atropine	0.5 mg	IV	Every 3–5 min (max = 3 mg)	
Hypomagnesemia/hypokalemia/torsades de pointe	Magnesium Sulfate	Same as above 2 g over 1–2 min	IV	Once	

Mean arterial pressure = diastolic BP + 1/3 (systolic BP – diastolic BP).

Air embolism occurs when air bubbles pass from the extracorporeal circuit into the patient's bloodstream. Life-threatening air embolism has become extremely rare due to the safety mechanisms integrated into modern dialysis machines, including air-foam detectors. Nevertheless, defects in tubing or dialyzer manufacturing or human errors, such as improper manipulation of tubing/catheter, medication administration or a breach in the venous line of the catheter, can still result in small air bubbles that may not trigger the machine's alarm, potentially causing long-term injuries to the lungs and brain [1, 2, 35]. If a significant amount of air enters the systemic circulation, reaching the right heart and pulmonary artery, the patient may experience sudden onset of dyspnea, hypoxia or cardiac arrest. If the air enters the cerebral arteries, the patient will present with neurological signs, seizure, stroke or cardiac arrest. Management of air embolism requires disposing of the extracorporeal blood, administering high-flow oxygen in case of pulmonary embolism and appropriate patient positioning [1, 2] (Box 1).

Anaphylaxis presents with sudden airway swelling, wheezing, persistent coughing or cardiac arrest with or without skin and mucosal changes [14, 15]. Dialysis-related causes include type A allergic reactions to the dialyzer, to heparin (or other drugs) or sterilization methods of circuit components [1, 2]. Immediate management involves stopping dialysis without returning blood, administering intramuscular epinephrine (adrenaline) into the anterolateral thigh and a saline bolus [14, 15] (Table 1). For resistant cases, noradrenaline may be used [31].

Airway obstruction

In addition to anaphylaxis, airway obstruction can occur from choking on a foreign body while eating during hemodialysis. Airway should be assessed by checking if the patient can speak, has a strange voice or exhibits stridor [14]. Management of foreign body airway obstruction includes performing five sharp back blows between the shoulder blades, repeated twice, and if unsuccessful, followed by Heimlich abdominal thrusts and encouraging the patient to cough. If these measures are unsuccessful, an attempt to remove a visible foreign body, using Magill forceps, should be made [36]. Oxygen should also be administered.

Breathing

Abnormal breathing is assessed by checking the respiratory rate, oxygen saturation (SpO2), chest symmetry, abdominal breathing, jugular vein distention, cyanosis and lung sounds. Patients with pulmonary edema, chronic obstructive pulmonary disease (COPD) exacerbation or asthma often prefer sitting. Pulmonary emergencies during hemodialysis include pulmonary embolism, asthma, acute pulmonary edema, bronchopneumonia or pneumothorax. Respiratory distress is common among hemodialysis patients, accounting for 27% of medical emergencies in this population [3]. Pulmonary embolism should be suspected in patients with sudden progressive dyspnea and no known pulmonary disease [15]. It requires high-flow oxygen, urgent computed tomographic pulmonary angiography and anticoagulation [15]. Pulmonary edema, typically at the start of dialysis or during blood transfusion, requires additional ultrafiltration. Management of any respiratory distress includes high-flow oxygen (Table 1).

Circulation

Circulation is assessed by looking for signs of hemodynamic instability, shock (septic, anaphylactic, cardiogenic, cardiac tamponade), arrhythmia and acute coronary syndrome. The

most common type of arrhythmia in hemodialysis patients is atrial fibrillation with a prevalence of approximately 11%. It frequently occurs during the dialysis session, potentially leading to hemodynamic instability [37]. Cardiac tamponade is another critical concern and may develop in 10%–20% of patients with dialysis-associated pericarditis [1]. Additionally, cardiogenic shock represents a significant cause of systemic hypoperfusion in this population. Its incidence has risen markedly over the past two decades, from 275 to 578 cases per 100 000 patients [38].

The first sign of circulatory dysfunction to be checked is the capillary refill time and it should not exceed 2–3 s if tissue perfusion is adequate. BP and heart rate should be checked. When signs of circulatory dysfunction are present, dialysis should be stopped and blood returned to the patient. An IV bolus of 500 mL saline is administered aiming for a mean arterial pressure ≥ 65 mmHg. The physician should check for signs of ischemia or arrhythmia on a 12-lead ECG. Urgent percutaneous intervention should be planned in case of ST-elevation myocardial infarction (STEMI) and aspirin 150–300 mg given [14, 31]. Atrial fibrillation requires administering IV amiodarone. In case of suspected septic shock, lactate should be measured, blood cultures obtained and broad-spectrum antibiotics started. In case of septic shock and lactate ≥ 4 mmol/L, a rapid administration of 30 mL/kg of IV saline is recommended. In the absence of response to fluid resuscitation, the patient is transferred to the ICU [31, 39].

Disability

Disability in hemodialysis is common and includes neurological events, including altered mental status, seizures, severe hypoglycemia, opiate overdose, stroke or the now-rare dialysis disequilibrium syndrome [40]. Hypoglycemia should be suspected in patients with diabetes who develop loss of consciousness. Stroke risk is high in patients on hemodialysis with ischemic stroke at 103 and hemorrhagic stroke at 75 per 10 000 person-years [41]. It is assessed using FAST (face, arm, speech, time to call) [31], AVPU (alert, verbal, pain and unresponsive) or Glasgow score (Box 2). Seizure should also be suspected as 8.8% of hemodialysis patients encounter epilepsy [42]. Pupils should be checked for brain mass (unequal pupils) or opiate overdose (small pupils). The management depends on the cause. Hemodialysis should be stopped and blood returned to the patient. IV glucose should be administered in case of hypoglycemia. When stroke is suspected, head and neck imaging should be quickly performed [14, 43, 44]. The European Stroke Organization suggests against routine BP lowering in patients with suspected stroke in the pre-admission setting [43] (Box 1). In case of epilepsy, antiepileptic drugs should be administered intravenously. Supplemental oxygen should only be provided to maintain SpO2 $>94\%$ [31, 44].

Box 2. Glasgow score

Eyes opening	Verbal response	Motor response
1. Spontaneous	1. Orientated	1. Obey commands
2. To sound	2. Confused	2. Localizing pain
3. To pressure	3. Inappropriate words	3. Normal flexion to withdraw from pain
4. None	4. Incomprehensible sounds	4. Abnormal flexion
	5. None	5. Abnormal extension
		6. None

Score interpretation: 3–8 severe, 9–12 moderate.

Exposure or environment

The final step would be performing a full body examination from head to toe, back to front, looking for signs of injury, infection, hypo- or hyperthermia, missed in the initial assessment [14, 15, 31].

Additional information

After patient bedside assessment, the full medical history should be checked in the patient's chart, as well as recent laboratory results, and the full list of medications.

Systematic approach in case of cardiac arrest: CAB method

Decision to resuscitate and patients' wishes

One of the dilemmas that healthcare providers face in case of cardiac arrest is whether the patient is a candidate for CPR, especially if cardiac arrest results from a reversible cause [45]. Some old studies from the UK, Canada and the USA showed that 48%–87% of dialysis patients wished to receive CPR [46–48]. However, in the Canadian survey only 25% of patients gave advanced directives to continue dialysis in severe stroke, severe dementia or coma [47]. A recent paper by Bernacki *et al.* analyzed 876 dialysis patients' preferences and showed that their response to end-of-life care is not always aligned with CPR preference [49]. Indeed, 84% wanted CPR and 16% chose "do not resuscitate (DNR)" but among the DNR group, 9% chose mechanical ventilation and 3.5% valued life prolongation [49]. Despite some ambivalence in patients' preferences, documented patient's advanced directives should be respected [45].

CAB: the universal approach

Circulation

The first actions are to call an emergency number, start chest compressions and ask colleagues to bring the automated external defibrillator (AED) (Fig. 3). Calling an emergency number in hemodialysis showed a better Return of Spontaneous Circulation (ROSC) [10]. The patient should be put in the supine position and there is no need to move the patient to the floor. There is no evidence of the utility of putting a backboard.

High-quality CPR is prompt and includes continuous uninterrupted chest compressions that should be applied at a frequency of 120 per minute, at the lower half of the sternum, with straight arms, and pressing down on the sternum at least 5 cm (but not >6 cm). The person applying the CPR should change, if possible, every 2 min (to avoid fatigue and ensure effective compressions).

Defibrillation is the next step and using an AED is standard practice in hemodialysis units. Nurse-led AED placement should be encouraged: early defibrillation is crucial and improves survival [14]. The first shock (150–200 Joules) is effective in 86%–98% of cases [45]. If the hemodialysis machine is not defibrillator-proof, it should be disconnected from the patient according to the International Electrotechnical Committee standards [14]. When the AED is ready, it is important to ensure that the chest is dry, the trinitrate patch removed and the oxygen bottle moved away. One patch of the AED should be placed on the left lateral of the chest and another below the right clavicle. If the patient has a pacemaker, it will be placed one inch below or on the back.

Airway

Basic airway management consists of maintaining the airway open, checking for any obstruction. A Guedel pattern airway or OPA, with an appropriate size, is placed to free the airway. The highest possible oxygen concentration should be given to ensure oxygen delivery to the brain.

Breathing

Ventilation should be ensured as early as possible [50]. This is usually achieved with a self-inflating bag attached to a facemask or an advanced airway. Each breath should be delivered over 1 s with the chest visibly rising. CPR should be provided using a 30:2 compression–ventilation ratio. If nobody in the hemodialysis unit is trained to intubate, it is advisable to wait for the emergency team and a skilled physician to avoid interrupting chest compressions.

Additional interventions

Intravenous medications

The VA can be used for drug administration during emergencies. Heparin should be removed from the catheter before drug administration. A saline flush should be given after drug administration to make sure it reaches the circulation. In case of asystole, epinephrine should be administered very early at a dose of 1 mg IV every 3–5 min. In case of ventricular fibrillation, epinephrine is given after three shocks have been administered then every 3–5 min, amiodarone 300 mg IV is needed after the third shock and 150 mg after the 5th shock [50]. Lidocaine is an alternative if amiodarone is unavailable [50] (Table 1).

Additional actions related to the hemodialysis context

A cardiac arrest occurring during the first minutes of the session, after the long interdialytic interval, is highly suspicious of hyperkalemia. Hyperkalemia requires administration of calcium gluconate and continuing dialysis treatment.

A cardiac arrest that occurs at the end of the session is probably secondary to ventricular fibrillation or torsade de pointes due to hypokalemia or hypomagnesemia [11, 51]. Although the fatal risk of hyperkalemia is well known within the dialysis setting, less emphasis is found on the arrhythmia risk with hypomagnesemia and hypokalemia [11, 51]. This should be kept in mind and requires administration of magnesium sulfate and stopping dialysis.

Duration of resuscitation

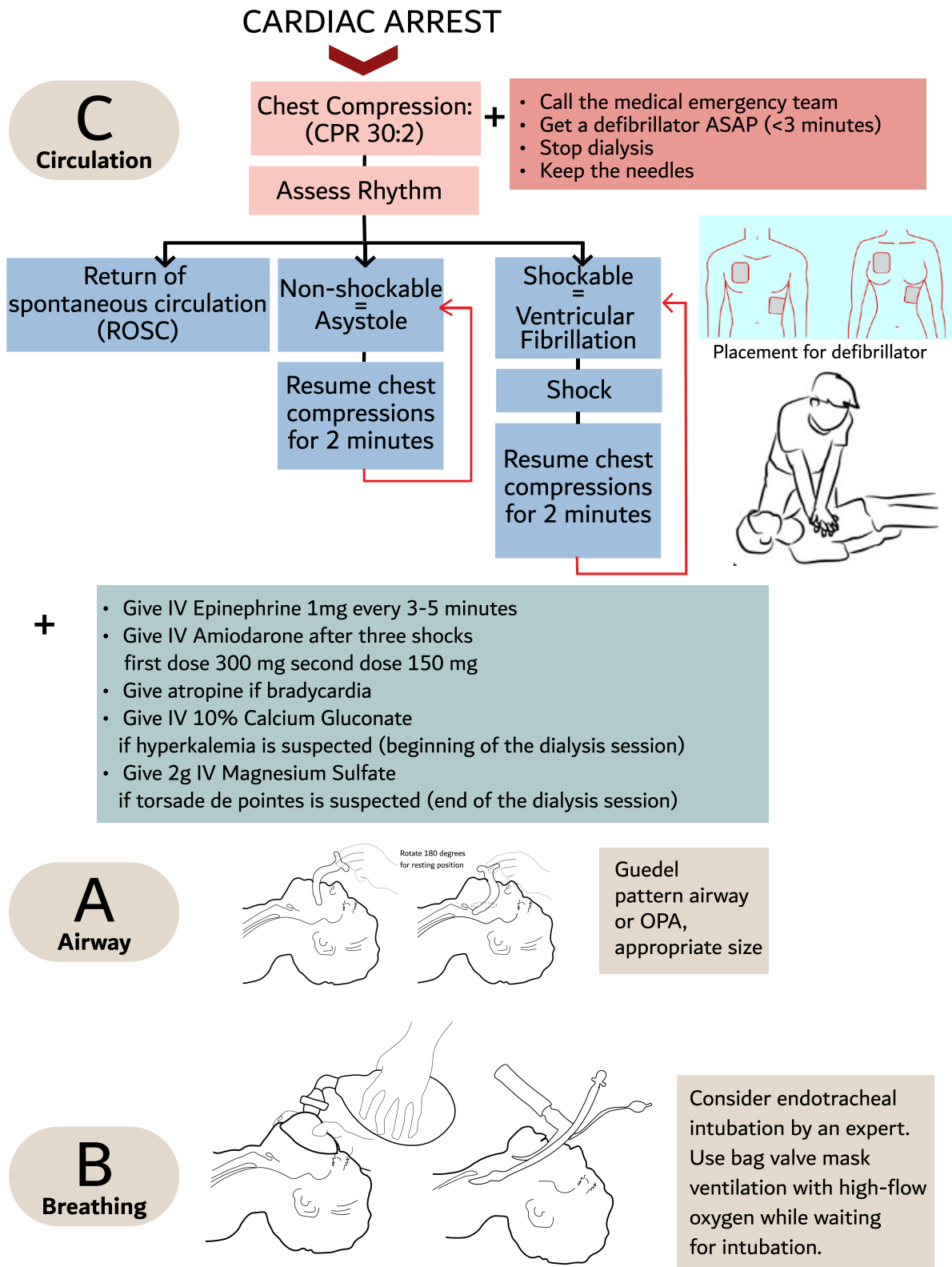
The decision to terminate CPR in a dialysis patient is often taken by the treating nephrologist. CPR should go on until a reversible cause is corrected.

Return of spontaneous circulation

Pulse and BP should be checked to confirm ROSC. Medical care after ROSC is very similar to any medical emergency using the ABCDE approach.

Cardiac arrest in low-resource settings

Data on the management of cardiac arrest in low-resource settings remain limited [52]. Existing studies, in the general population, have identified several critical gaps in the chain of survival, including delayed recognition of cardiac arrest, delayed initiation of CPR, delayed defibrillation and delayed transfer to ICUs [52].



trained to apply the ABCDE and CAB methods as rapidly and systematically as possible.

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AUTHORS' CONTRIBUTIONS

M.A. contributed to the first draft. C.C. and M.J. contributed to the extensive revision. All authors revised and approved the final manuscript.

DATA AVAILABILITY STATEMENT

No new data were generated or analyzed in support of this research.

CONFLICT OF INTEREST STATEMENT

M.A. and C.C. have no conflict of interest. M.J. reports receiving speaker fees from Astellas, Astra-Zeneca, Bayer, Boehringer-Ingelheim, Menarini and Stada-EG; and consultancy fees from Astellas, Astra-Zeneca, Bayer, Boehringer-Ingelheim, Cardioresnal, CSL Vifor, GSK, Novo Nordisk, Stada-EG and Vertex. Since January 2019, he has been the Co-Chair of Kidney Disease: Improving Global Outcomes (KDIGO).

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